AD 736599

Technical Note N-1194

"Analysis of Off-Loading Cargo at the Beach"

by

J. G. Kirby

October 1971

Sponsored by

Naval Ship Systems Command

NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California 93043

44

ANALYSIS OF OFF-LOADING CARGO AT THE BEACH

Technical Note N-1194

55-018

by

J. G. Kirby

ABSTRACT

This report documents an experimental examination of the attainable cargo flowrate for two types of future landing craft: air cushion and planing. Both forklift and crane off-loading were considered, and the performance using 96"x108" large pallets was compared with that using 40"x48" pallets. It was found that the large pallet concept can increase the productivity of the forklift by more than 300% and the crane by approximately 200% over what is possible with the standard pallet

TABLE OF CONTENTS

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Naval Civil Engineering Laboratory Port Hueneme, California 93043	2a. REPORT SECURITY CLASSIFICATION Unclassified	2b. GROUP
3. REPORT TITLE Analysis of Off-Loading Cargo at the Beach		
4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)* Final; July 1970 - June 1971		
5. AUTHOR(S) *(First name, middle initial, last name)* Jeffrey G. Kirby		
6. REPORT DATE October 1971	7a. TOTAL NO. OF PAGES 40	7b. NO. OF REFS 11
8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) TN-1194	
b. PROJECT NO. 55-018		
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	
d.		
10. DISTRIBUTION STATEMENT Approved for public release; distribution unlimited.		
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Naval Ship Systems Command Washington, D. C. 20360	

13. ABSTRACT

This report documents an experimental examination of the attainable cargo flowrate for two types of future landing craft: air cushion and planing. Both forklift and crane off-loading were considered, and the performance using 96"x108" large pallets was compared with that using 40"x48" pallets. It was found that the large pallet concept can increase the productivity of the forklift by more than 300% and the crane by approximately 200% over what is possible with the standard pallet. /

DD FORM 1 NOV 65 1473 (PAGE 1)

S/N 0101-807-6801

UNCLASSIFIED

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Unloading						
Cargo						
Landing craft						
Beaches						
Amphibious operations						
Planing						
Ground effect machine						
Pallets						

INTRODUCTION

The Naval Ship Research and Development Laboratory (NSRDL), Annapolis, Maryland, is participating in the Amphibious Assault Landing Craft Program (Project S14-17). The goal of this program is to develop a new generation of high speed assault landing craft which will be operational in the midrange period (1975-1980).

The effective utilization of these new high speed craft for cargo transport will require that complementary high speed cargo handling methods be devised. Recognizing the importance of reducing the beach cargo handling portion of the ship-to-shore cargo transfer cycle, NSRDL requested the Naval Civil Engineering Laboratory (NCEL) during FY-69[1] to study the concept of using a large pallet. A FY-70[2] follow-on developmental task was also requested in which three prototype large pallets were designed, fabricated, and tested.

The culmination of the examination of the large pallet as a form of a large unit load was the assignment[3] of the present task; i. e., to experimentally measure the effect of the large pallet on the cargo off-loading abilities of two types of advanced landing craft - the air cushion vehicle (ACV) and the planing hull craft. Specifically, the primary goal of the task was to obtain a measure of the off-loading efficiency, as a function of pallet size, of two types of materials handling equipment (MHE) for both types of craft. The two secondary goals of the task were to determine the effect of ramp width on the forklift off-loading capabilities of the ACV and to compare the effectiveness of an 8x8x20-foot container off-loaded by a crane against that of the large pallet off-loaded by either a crane or forklift.

EQUIPMENT

Craft

Simulated cargo holds for each of the advanced landing craft were devised so that the off-loading data would accurately reflect the expected performance of the craft. A full scale mock up of the cargo well of the Bell C150-50 ACV was constructed. As shown in Figure 1, the cargo well with dimensions of 27' 4" wide by 66' 0" long was erected on a beached P-series pontoon barge located at the U. S. Naval Construction Battalion Center at Port Hueneme, California. The walls defining the well were constructed of 6 foot chain link fencing. Slats were inserted into the fence to give a visual reference of the wall. Access of the cargo well was provided via a 14-foot wide ramp that was fabricated to meet the preliminary design inclination specification of 14 degrees.

Figure 1. Mock-up of ACV cargo well.

The planing craft will offer a high transport speed capability, but will still address the beach in a manner similar to present day craft as may be noted in Figures 2 and 3. It is not anticipated that the planing craft will present a substantially different cargo well lay-out than exists with current craft. Thus the adequate simulation of the cargo well was deemed to be more dependent upon the provision of a surf environment than a dimensionally correct full scale mock-up. With this in mind, a representative current day craft (LCM-8), as shown in Figure 2, was selected to simulate the planing craft. Mechanical failures on the LCM-8 during the test program forced the substitution of a LCU for the later portion of the tests. The off-loading tests were conducted at the Naval Amphibious Base at Coronado, California. The beach slope at the test site was approximately 1:50.

Cargo

The two specific types of pallets compared in this study were the standard 40x48-inch double entry pallet and the NCEL 96x108-inch double entry wood pallet.*

The NCEL large pallet was constructed of 4x4 timbers with a plywood decking; it weighed approximately 700 pounds including tie-down straps. As may be noted in Figure 1, four standard pallets can be accommodated on the large pallet, provided the total weight does not exceed the 5-ton** design limit.

For the ACV off-loading tests, the mix of weights of the dummy pallets was adjusted as closely as possible to reflect the average percentage breakdown for POL, ammo, and general cargo usually found in an amphibious operation.*** The dummy standard pallets varied in weight from 676 pounds to 2,669 pounds; the large pallets varied from 6,304 to 9,852 pounds. Details of the actual pallet composition can be found in Appendix A.

---

*Details of design, test, and evaluation can be found in reference 2.

**Ton as used in this report refers to a short ton.

***Stanford Research Institute (page 21, reference 5)

5% POL @ 2100 lbs.
20% Ammo @ 3600 lbs.
75% general cargo @ 1500 lbs.

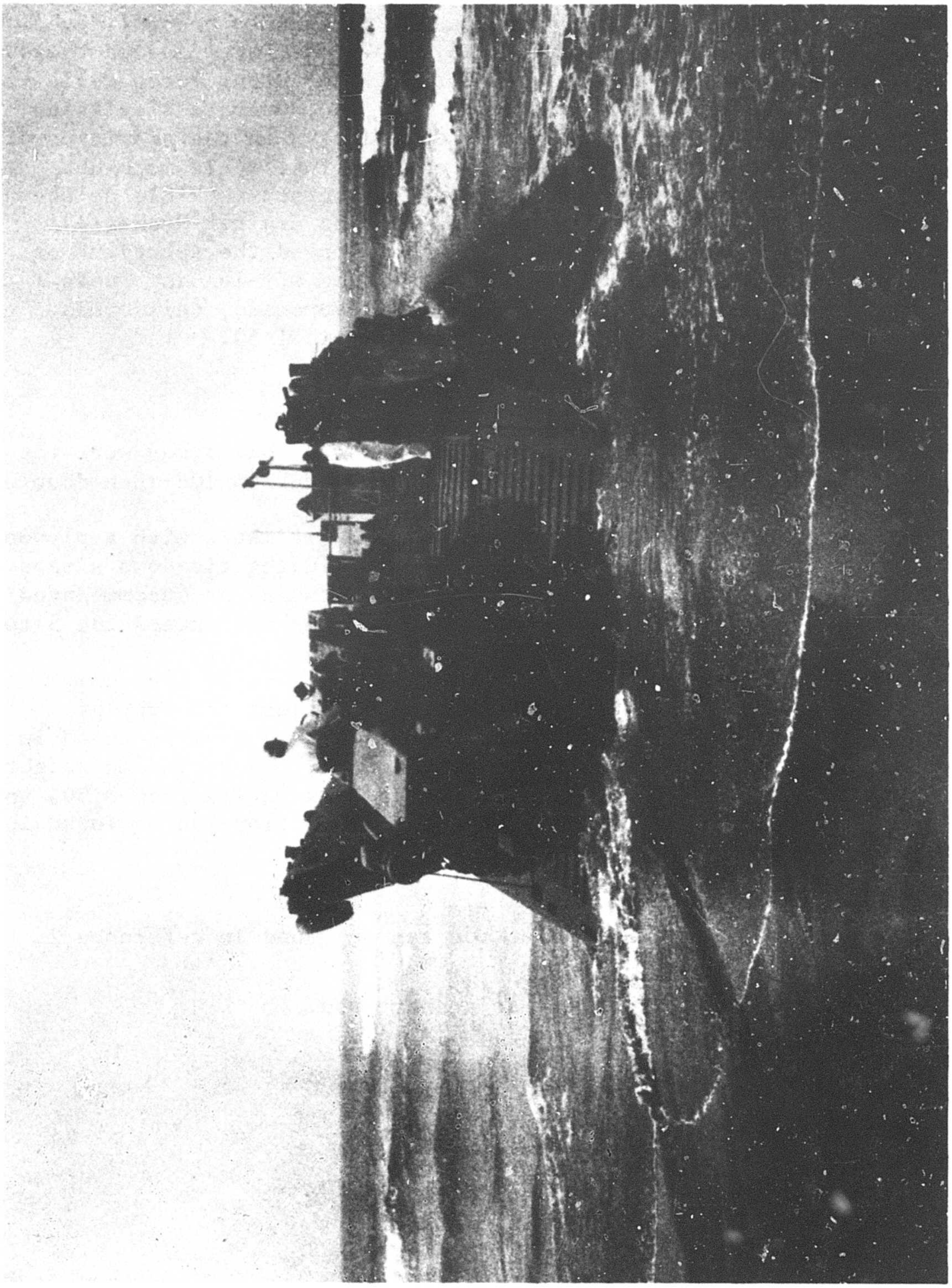


Figure 2. Mock-up of planing craft cargo well.

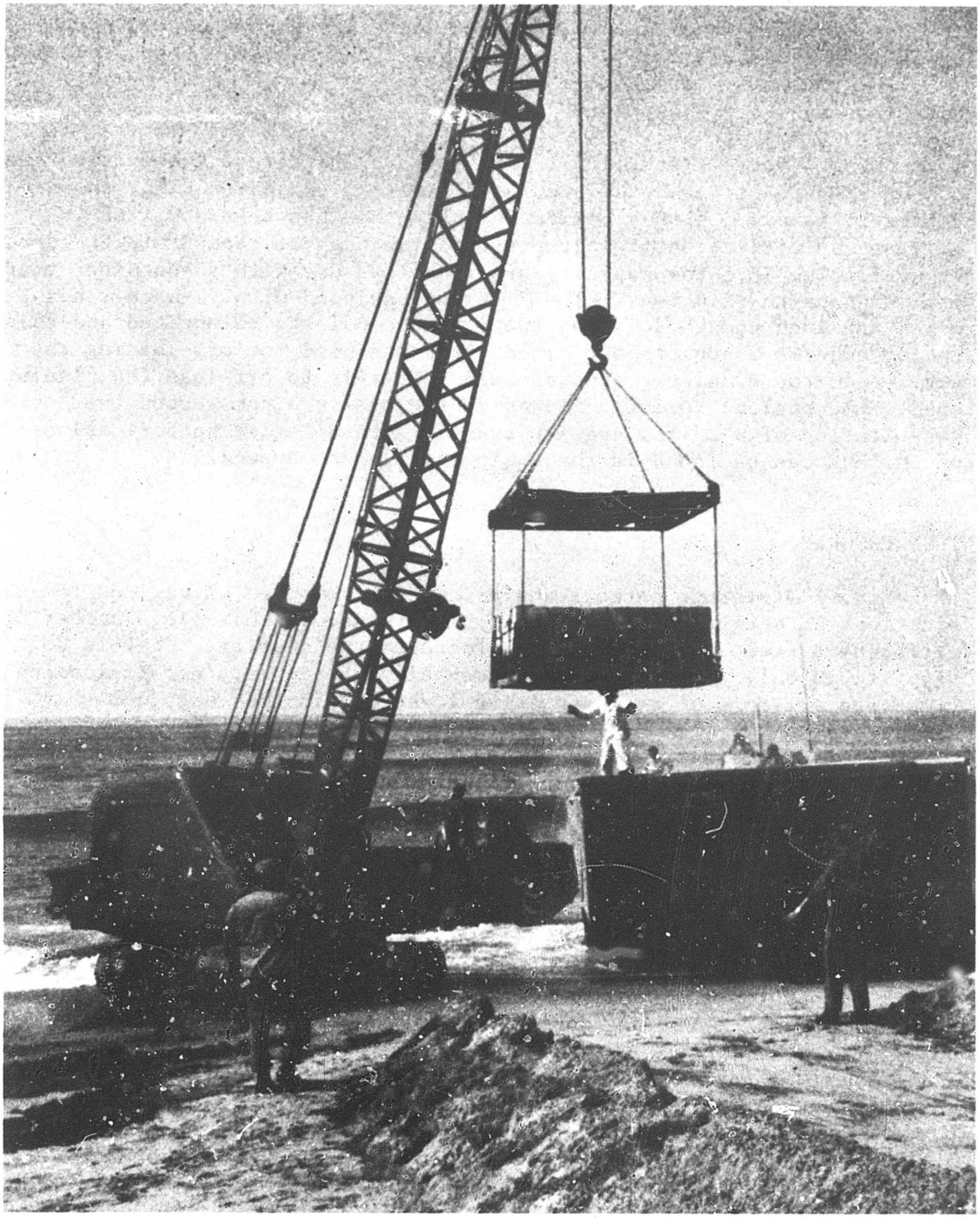


Figure 3. Use of LARK V during crane off-loading.

An 8x8x20-foot commercial freight container with a 44,800 pound gross weight capacity was also used for a portion of the test program.

Materials Handling Equipment

A rough terrain forklift (RTFL) and a crane were the only two types of MHE used to off-load the simulated crafts. The 5-ton RTFL, shown in Figure 2, is based upon a commercial unit that has been modified to military specifications. It represents the highest capacity RTFL currently available. A 5-ton capacity precludes its use with a container that can weigh up to 22.4 tons. The RTFL was equipped with 72-inch tines which are long enough to allow two standard pallets to engaged and raised end to end. A 25-ton rubber-tired crane was used for off-loading the ACV. A 10-ton crawler crane was used initially to off-load the planing craft. Mechanical failures midway in the test program forced the substitution of a 25-ton crawler crane. More detailed specifications of the MHE can be found in the equipment list of Appendix B.

TEST PROGRAM

Eleven different cargo transfer systems composed of various combinations of cargo, craft, and MHE were examined. This large number of different systems made a sampling procedure a necessity. That is to say, it was only feasible to experimentally obtain data on off-loading times for a sample of representative locations in the cargo well for each system.

Before representative locations for the dummy cargo loads could be selected, the maximum cargo capacity of each of the landing craft was determined on the basis of a square or weight limit. The geometric constraints used in determining the cargo per available deck space were: (a) no stacking of pallets, (b) 6" to 8" clearance between pallets and between pallets and well walls for crane off-loading, and (c) 6" to 8" clearance between pallets and 20" to 24" clearance between pallets and well walls for RTFL off-loading. The additional clearance was required for the RTFL since it did not have side-shifting forks. The average weight of one ton per standard* pallet and 15-ton per container* was used to determine the maximum transportable cargo load based upon weight limitations.

After the maximum cargo capacity of each craft had been determined, the loading diagrams of Appendix C were drawn to determine possible cargo loading configurations. These diagrams were then used to select the representative pallet locations to be used in the test plan.

Large pallets, standard pallets and an 8x8x20-foot container were off-loaded from the ACV with a crane. The ACV forklift off-loading tests consisted of off-loading standard pallets and large pallets.

---

*Reference 1, page 8.

A second order goal of this task was to determine the effect of ramp width on the time required for a forklift to off-load an ACV. Only two ramp widths were evaluated - full and constricted to approximately one half width. This comparison was accomplished by constructing a 14-foot wide ramp that met the preliminary design inclination specification of 14°. To simulate a full width configuration the ramp was placed with one edge in line with a side of the cargo well. Off-loading tests were then performed with either large or standard pallets placed in the well either close to the centerline of the ramp or adjacent to the ramp side of the well wall. The ramp was then moved to a center position of the entrance to the cargo well to approximate a constricted ramp. (See Figure 1) Off-loading tests were then conducted with each type of pallet placed adjacent to the walls and in the corners close to the ramp. For this test it was not necessary to conduct off-loading with the cargo placed close to the centerline of the ramp since that would be similar to a full width ramp configuration.

Both types of pallets were off-loaded from the LCM-8 (LCU) with the crane and RTFL. No container off-loading tests were scheduled for the planing craft tests.

TEST PROCEDURE

Using the normal one-ton per standard pallet and the previously stated clearance restrictions, it was determined that the ACV is weight limited and can only carry 75 standard pallets or 17 large pallets, even though more deck space is available. Both of these loads total to the 150,000-pound payload capacity of the ACV.

Similarly it was found by means of the loading diagrams of Appendix C that the cargo carrying capacity of the LCM-8 is deck space limited, and not weight limited as was the ACV. Specifically, the LCM-8 was found to be able to carry 27 standard pallets (27-tons) or 4 large pallets (17.4 tons). The additional clearance required for the RTFL reduced the standard pallet carrying capacity of the LCM-8 to 24 standard pallets (24-tons), when the RTFL was to be used for off-loading. However for crane off-loading, 6-inch clearance was adequate and 27 pallets could be carried. Either of these loads is far below the actual cargo weight capacity of 59.5 tons.

The forklift off-loading cycle was divided into the following six components:

1. Time to traverse distance from storage dump to ramp.
2. Time to climb ramp.
3. Time to lift off load.
4. Time to reach ramp.
5. Time to descend ramp.
6. Time to traverse distance to cargo dump and discharge load.

Times for the above six components of the off-loading cycle were recorded for both large and standard pallets placed in a variety of locations in the cargo well. The elapsed times for steps 2 through 5 for each pallet type were added and then plotted as a function of the distance of the cargo from the upper edge of the ramp. A regression analysis was performed on each group of data points corresponding to a specific type of pallet and ramp width and the derived emperical equation was drawn on the same graph as the plotted points. These graphs, which can be found in Appendix D, give a good estimation of the time required for a RTFL to off-load a pallet from any location in the ACV cargo well. The total time for a forklift to off-load a fully loaded ACV was calculated by summing the times obtained from the pertinent graph for each pallet location on the loading diagram.

Crane off-loading tests were performed with the standard pallet, the NCEL large pallet and an 8x8x20-foot container. The crane cycle was divided into eight definable components:

1. Time to adjust crane position.
2. Time to raise hook to clear craft.
3. Time for the boom to swing to a position over the load.
4. Time to hook-up cargo and lift-off of the deck of the craft.
5. Time until the boom swing is started.
6. Time until the boom swing stops.
7. Time to set down cargo.
8. Time to unhook cargo.

The times for each of the eight components of the off-loading cycle were recorded. Figure 1 indicates how the crane was positioned so that the boom would be able to clear the thickness of the Bell ACV well walls. Assuming a standard military load of 15-ton* per container (gross), the loading diagram C-3 of Appendix C indicates that the ACV can carry a maximum of 5 containers.

As with the forklift tests, only a representative sample of cargo positions were experimentally off-loaded. The pallets and container were placed in various positions in the cargo well to determine the extent to which the crane could reach the cargo by only using different combinations of boom angle and swing. The cumulative times of components (2) through (8) for all pallets of one type and containers off-loaded from one crane position were averaged to obtain an off-loading time per unit of cargo. Also recorded were the distances the crane was required to move to assume a new position and the time interval necessary to do so; these figures were used to calculate the rate (ft/sec) at which the crane re-positions. The total time to unload a fully loaded ACV was calculated by combining the number of off-loading times per unit of cargo with the time required for the crane to make the necessary position changes.

---

*Normal load varies 10-16-ton (reference 1, page 5).

Instead of having to record times from only a few of the possible cargo locations and then extrapolate, as was necessary with the ACV, the relatively small cargo capacity of the LCM-8 allowed a more direct approach to the determination of off-loading times. The large pallet off-loading tests were conducted with the craft fully loaded; for the standard pallet off-loading tests, a two-third cargo load was used.

The planing craft test program highlighted the difficulty in working in the surf zone. Equipment failures also occurred during the first three days of the test program; three different LCM-8s and one crane had mechanical failures. In order to complete the test program, an LCU and a different crane were substituted on the fourth and final day. This change in craft and MHE midway in the data taking process did tend to make an adequate comparison of the effectiveness of the MHE and pallet consolidation methods difficult.

DISCUSSION OF TEST RESULTS

During the ACV tests it was observed that the differences in off-loading times were not a function of pallet weight, but of pallet type. All large pallets were off-loaded in approximately the same time regardless of weight; the same was true of the standard pallets. In view of these findings, lightweight pallets with low vertical centers of gravity were used for the planing craft in order to (a) increase the vision of the forklift operator and (b) for a larger factor of safety for the personnel working in the vicinity of the pallets. No bias in the test results was observed by performing these substitutions.

In order to adequately compare the effect of cargo type, craft type, type of MHE, and ramp width on off-loading productivity, eleven cargo transfer systems were examined. Table 1 indicates the calculated time required for each cargo transfer system to transfer the cargo from a fully loaded craft to a temporary cargo dump adjacent to the craft. The off-loading times of Table 1 were used to calculate the off-loading rate in terms of tons per hour. Since the observed off-loading time was independent of pallet weight, the accepted average weight of one ton per standard pallet was used in the calculations instead of the actual dummy pallet weight. Since it was felt that a similar conclusion as to the independence of weight in off-loading time for containers would be reached, it was not deemed necessary to place a dummy load in the actual container off-loaded. For the calculated off-loading rate, however, a 15-ton gross weight was assumed.

The calculated off-loading rates for each of the eleven cargo transfer systems were ranked in order of productivity in Table 2. The off-loading rates are expressed both in terms of the lift weight and the actual cargo weight (adjusted for tare weight of container or large pallet). Since the average weight of a standard pallet is one ton, the off-loading productivity indicated in Table 2 can be considered as being expressed as either in tons per hour or in standard pallets per hour. The comparison

of the productivity of the large pallet with a RTFL or crane versus (a) the forklift with one standard pallet, (b) the forklift with two standard pallets and (c) the crane with the standard pallet can be noted in this table.

Table 2 indicates that on a ton per hour ranking basis, the 8x8x20 container is clearly a superior cargo transfer method. (1.6 times as productive as the next alternative.) The next three most productive cargo transfer systems, which are numerically close in terms of productivity, use the RTFL and the large pallet. This gives a fairly clear indication of the all around flexibility of the RTFL and large pallet with all craft types and well configurations. The remaining seven cargo transfer systems offer low productivity.

The ranking of Table 2 disregards the differences in manpower required by the different cargo transfer systems. The RTFL functions with only two men - an operator and a spotter on the craft. The crane with either the large or standard pallet requires six men - an operator, two slingmen on the beach, two slingmen on the craft, and one signalman on the craft. Four additional slingmen would be required for container off-loading.

The entries in Table 2 were divided by the number of men required for each cargo transfer system to produce a productivity measure in tons per man hour. Table 3 indicated by using tons per man-hour as a ranking criterion a considerable change in the productivity order of Table 2 occurs. The forklift and large pallet combination, which was previously ranked a distant second in terms of tons per hour, becomes substantially more productive than its nearest rival.

Table 3 and Figure 2 also indicates forklift off-loading was not noticeably more difficult for the LCM-8 (LCU) than for the ACV. This was not the case, however, for the crane off-loading. Much difficulty was encountered in working in a surf environment. One of the major problem areas was the difficulty of maintaining the required relative positions of the crane and LCM-8 long enough to hook up the load and lift it clear of the craft. During the first crane off-loading test, the LCM-8 bumped the crane, which was down wind, several times. This highly dangerous situation was remedied, as shown in Figure 3, by using a LARK V to hold the LCM-8 in a relatively stationary position for the remainder of the crane test program. Unfortunately nothing could be done about the surf action which tended to undermine the crane and reduce its stability. For the crane off-loading of the planing craft only the personnel directly involved with the cargo handling (crane operator, slingmen, and signalmen) were included in the man-hour calculations. Strictly speaking, the LARK V crew of two, which was only required for crane off-loading, should also be included. However, since their inclusion did not change the relative rankings, they were disregarded.

As shown by Figure 4, an area of approximately 20 feet in length and 9 feet in width on either side of the constricted ramp (360 square feet total) was found to be not accessible by the forklift. This "lost" deck space represents approximately 20 percent of the total available deck space. However, since the ACV is weight limited and not area limited (for palletized cargo per previous assumptions), this did not reduce the cargo carrying capacity of the craft.

Table 1. Calculated time each cargo transfer system requires to off-load a fully loaded craft

Craft	MHE*	Cargo	Off-Loading Time (min)
ACV	Crane	5 containers	11.0
ACV	Crane	17 large pallets	29.2
ACV	Crane	75 standard pallets	62.5
ACV (full ramp)	Forklift	17 large pallets	18.7
ACV (full ramp	Forklift	75 standard pallets	69.6
ACV (constricted ramp)	Forklift	17 large pallets	22.6
ACV (constricted ramp)	Forklift	75 standard pallets	71.5
Planing	Crane	4 large pallets	46.0
Planing	Crane	27 standard pallets	54.8
Planing	Forklift	4 large pallets	4.9
Planing	Forklift	24 standard pallets	28.3

*All tests were conducted with one MHE; off-loaded cargo was placed adjacent to craft.

Table 2. Calculated cargo transfer systems ratings in ton/hour.

Cargo Transfer System	Lift Wt	Productivity Adjusted for Tare Weight[a]			
Craft/MHE/Cargo/(Ramp)[b]	Tons/Hr	Tons/Hr	Large Pallet Relative to Standard Pallet	Large Pallet Relative to 2 Standard Pallets	Relative to Next Lower System
ACV/crane/container	411	351	---	---	1.61
ACV/forklift/LP (FW)	237	218	3.4	1.8	1.11
Planing/forklift/LP	214	197	3.9[c]	2.3[c]	1.09
ACV/forklift/LP (CW)	196	180	2.9	1.6	1.29
ACV/crane/LP	152	140	1.9	---	2.12
ACV/crane/SP	72.0	72.0	---	---	1.11
ACV/forklift/SP (FW)	64.6 (118.0)[d]	64.6 (118.0)[d]	---	1.8	1.03
ACV/forklift/SP (CW)	62.5 (114.5)[d]	62.5 (114.5)[d]	---	1.8	1.23
Planing/forklift/SP	51.0 (87.0)[d]	51.0 (87.0)[d]	---	1.7	1.72
Planing/crane/SP	29.6	29.6	---	---	1.41
Planing/crane/LP	22.8	21.0	0.7	---	----

[a]The tare weight of the container is obviously a function of the container type (steel, aluminum, or plywood). Reference (5) and (6) indicated that FRP plywood containers have the lowest life cost. It is thus reasonable to assume that this type has the highest probability of being used and therefore its tare weight of 4,375 pounds was used in this report.

[b](FW)-full width ramp (CW)-constricted ramp; LP-large pallet; SP-standard pallet.

[c]The forklift LP off-loading were performed with a LCU whereas the standard pallets were off-loaded from a LCM-8. The added maneuvering space in the LCU probably is the reason this number is so high compared to the others.

[d]Estimated productivity for the RTFL to lift two pallets end to end at a time (no stacking). This is possible since the RTFL used was equipped with 72" forks.

Table 3. Calculated/cargo transfer system ratings in ton/man-hour.

Cargo Transfer System	Lift Wt	Productivity Adjusted for Tare Weight[a]			
Craft/MHE/Cargo/(Ramp)[b]	Tons/MH	Tons/MH	Large Pallet Relative to Standard Pallet	Large Pallet Relative to 2 Standard Pallets	Relative to Next Lower System
ACV/forklift/LP (FW)	119	109	3.4	1.8	1.11
Planing/forklift/LP	107	98.4	3.9[c]	2.3[c]	1.09
ACV/planing/LP (CW)	98	90.0	2.9	1.6	2.57
ACV/container	41.1	35.1	---	---	1.09
ACV/forklift/SP (FW)	32.3 (59.0)[d]	32.3 (59.0)[d]	---	1.8	1.03
ACV/forklift/SP (CW)	31.3 (57.3)[d]	31.3 (57.3)[d]	---	1.8	1.23
Planing/forklift/SP	25.5 (43.4)[d]	25.5 (43.4)[d]	---	1.7	1.09
ACV/crane/LP	25.4	23.4	1.9	---	1.95
ACV/crane.SP	12.0	12.0	---	---	2.43
Planing/crane/SP	4.94	4.94	---	---	1.41
Planing/crane/LP	2.80	3.50	0.7	---	----

[a] The tare weight of the container is obviously a function of the container type (steel, aluminum, or plywood). Reference (5) and (6) indicated that FRP plywood containers have the lowest life cost. It is thus reasonable to assume that this type has the highest probability of being used and therefore its tare weight of 4,375 pounds was used in this report.

[b] (FW)-full width ramp; (CW)-constricted ramp; LP-large pallet; SP-standard pallet.

[c] The forklift LP off-loading were performed with a LCU whereas the standard pallets were off-loaded from a LCM-8. The added maneuvering space in the LCU probably is the reason this number is so high compared to the others.

[d] Estimated productivity for the RTFL to lift two pallets end to end at a time (no stacking). This is possible since the RTFL used was equipped with 72" forks.

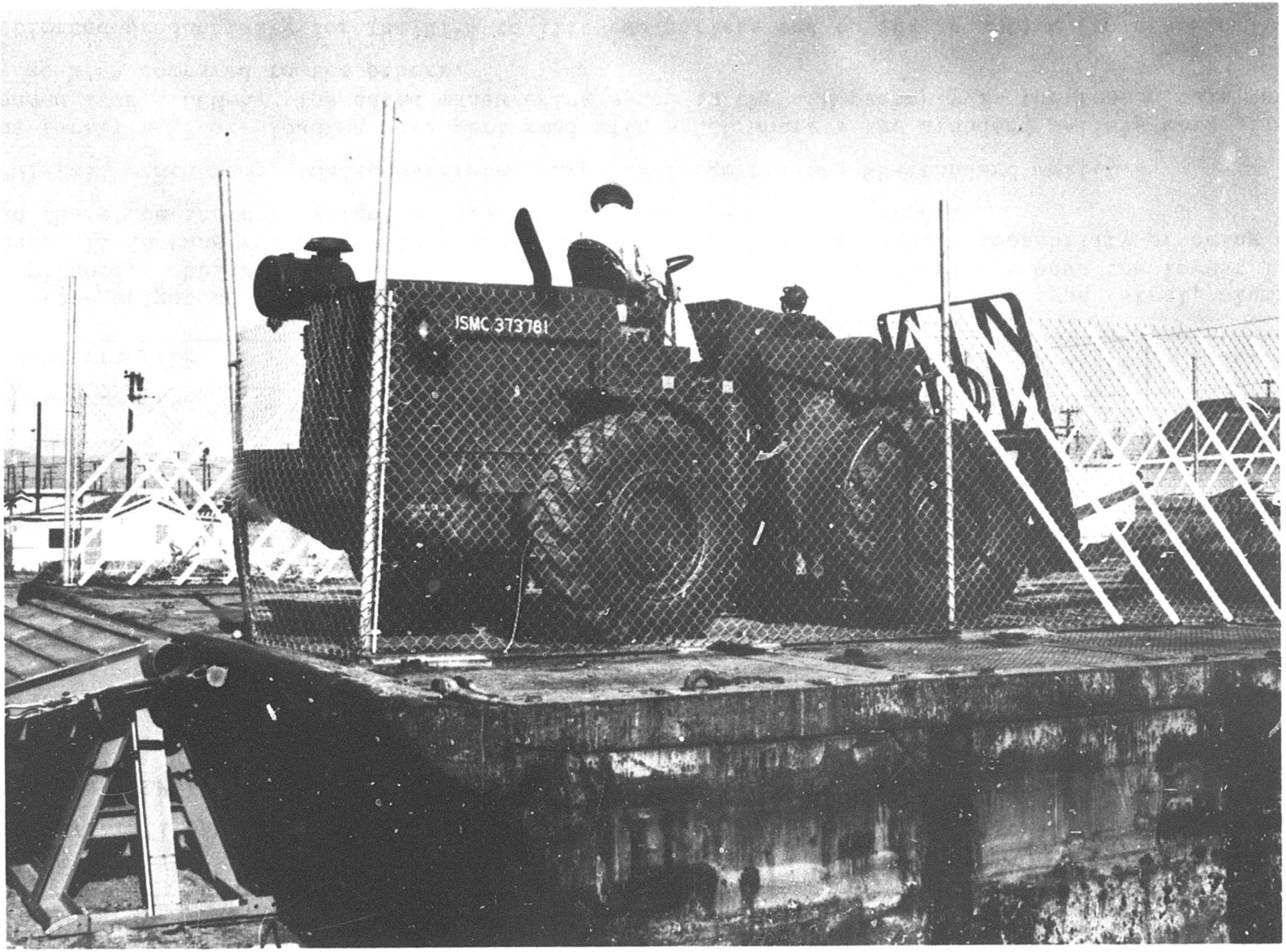


Figure 4. Lost deck space due to constricted ramp.

The rankings of Table 3 indicate that a 12 percent greater off-loading rate of large pallets by RTFL can be expected if a full width ramp is available instead of a constricted ramp. The standard pallet off-loading tests indicated that only a 3 percent off-loading advantage was obtained with the full width ramp. It should be noted, however, that the non-excessible deck space in the constricted ramp configuration required the loading diagram to be altered slightly. As shown in Figure C-1 of Appendix C, the six pallets that would have normally been loaded in the unaccessible area for a full width ramp configuration were moved to a position nearer to the centerline of the ramp and closer to the front of the craft.

The previously mentioned NCEL analytical study[1] of cargo off-loading of future landing craft estimated that the large pallet should improve the productivity of the RTFL by 3.8* and the double stacking of standard pallets would increase forklift effectiveness by 1.8.* Table 2 and 3 indicate that the large pallet did increase the forklift productivity by 3.4 or slightly below predicted value. The RTFL equipped with 72-inch tines allowed two pallets to be engaged end to end; consequently the effectiveness of the forklift to move standard pallets was almost doubled. This procedure eliminated the additional time that would have been required if shorter forks had dictated the necessity of the stacking the pallets in order to lift two at a time.

The calculations used to compute the off-loading time for a fully loaded craft with a constricted ramp were based upon the figures of Appendix D. These are "smooth" graphs in the sense that several exceedingly high times are not reflected in the curves. Generally speaking, with a constricted ramp the pallets placed close to the side walls near the front of the craft are difficult to pick up. The first few rows of pallets for both crafts are difficult to pick up because the forklift must maneuver while still on the ramp. The reduced visibility while in this position as indicated by Figure 5, makes it extremely difficult for the operator to engage and lift the pallet. For example during the large pallet off-loading, the operator occassionally engaged the pallet with the forklift tines not parallel to the deck surface. When this occurs, the large pallet is usually severely damaged.

Table 2 and 3 point out that the large pallet is not as effective a method of load consolidation for crane off-loading as for forklift off-loading. The principal reason is that the hooking-on time is considerable greater for the safety hook and lifting eye arrangement found on the large pallet (shown in Figure 6) than it is for the simplistic pallet bar slings used for the standard pallets indicated in Figure 7.

One problem area that was noted during the off-loading of the LCM-8 was that the traction bars caused considerable damage to the standard pallets that were accidentally slid on the deck. This occurred both during forklift off-loading and crane off-loading. Figure 8 indicated the nature of this problem area.

---

*Reference 1, page 16.

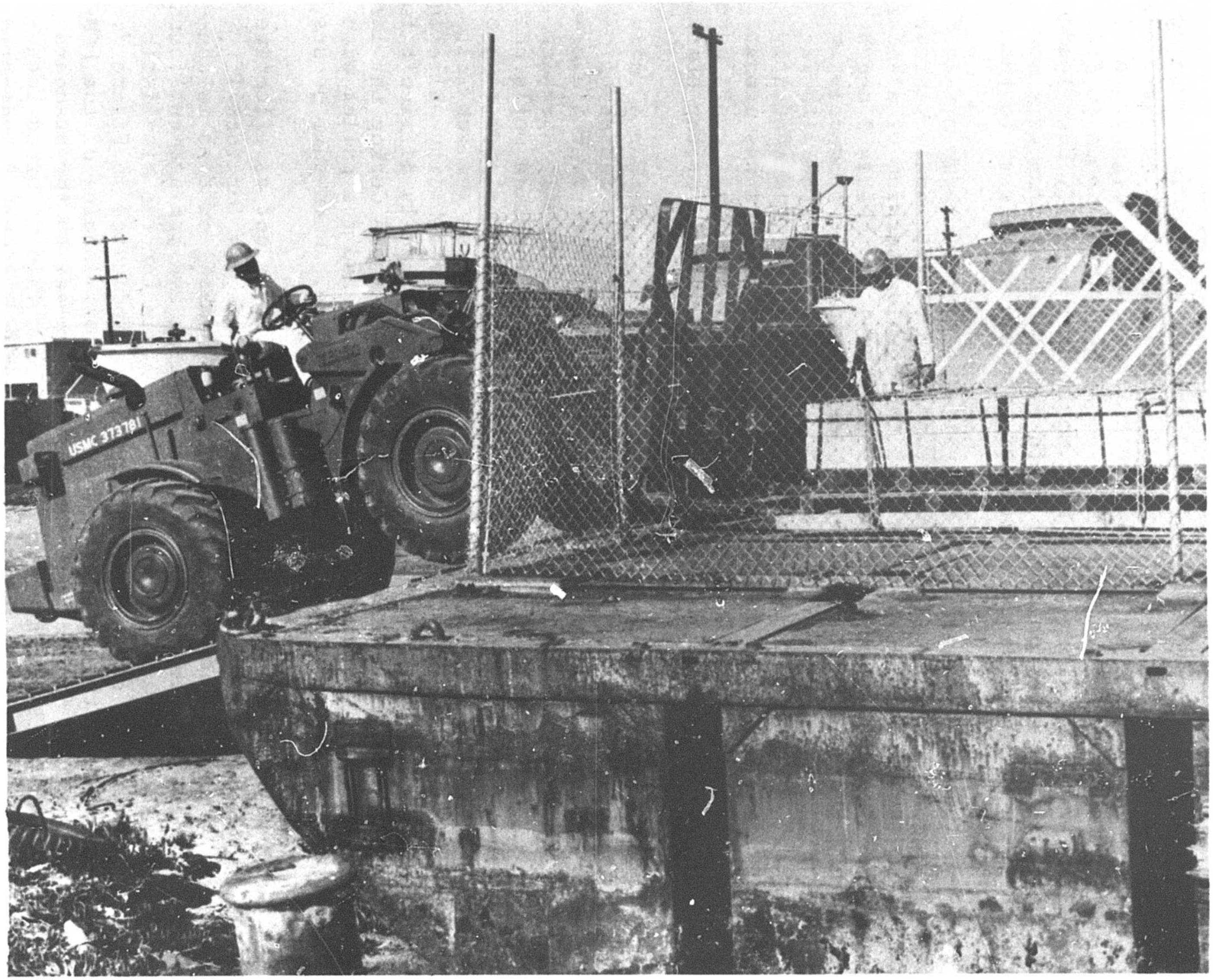


Figure 5. Difficulty in lifting pallet close to ramp.

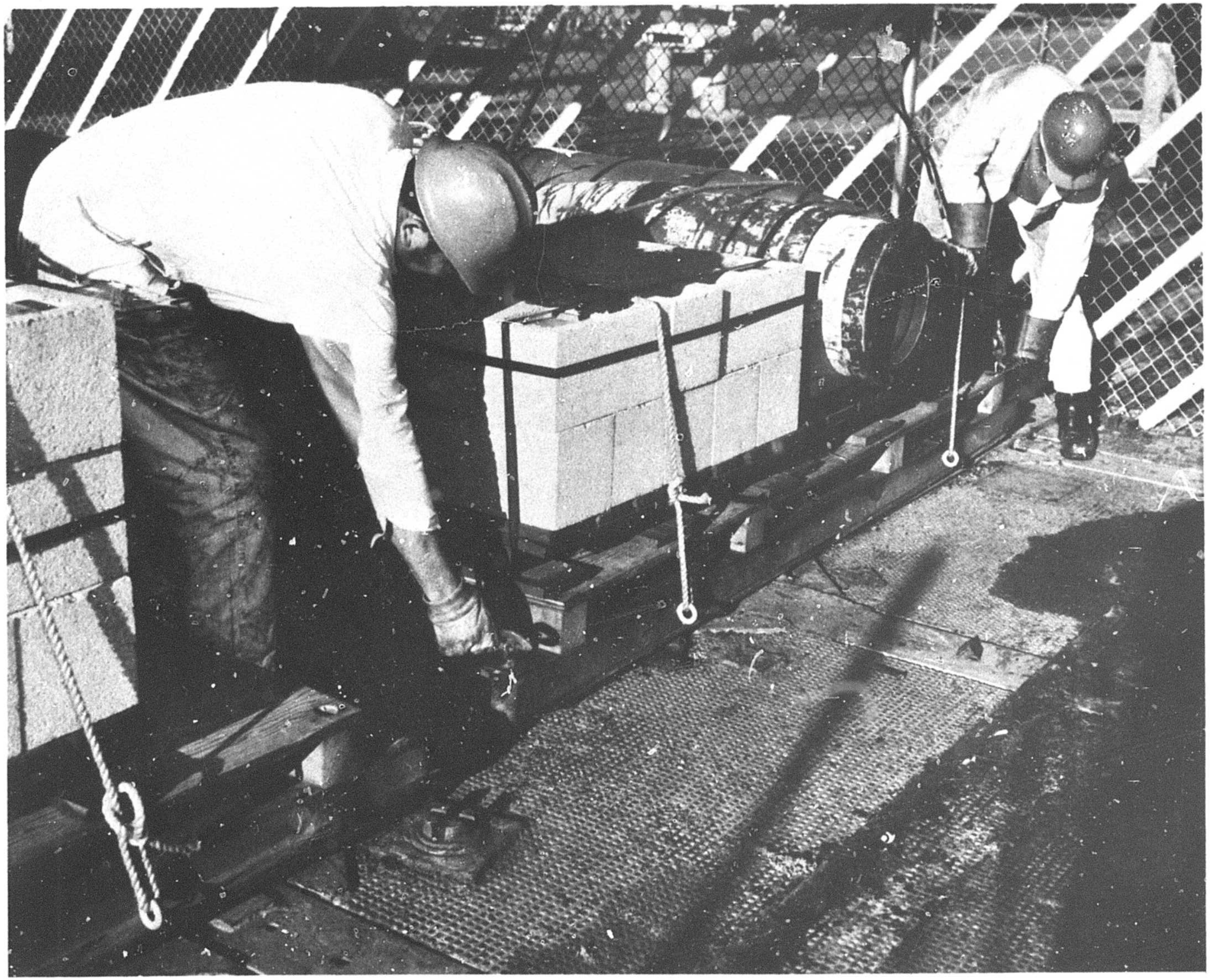


Figure 6. Hooking up a NCEL large pallet for crane off-loading.

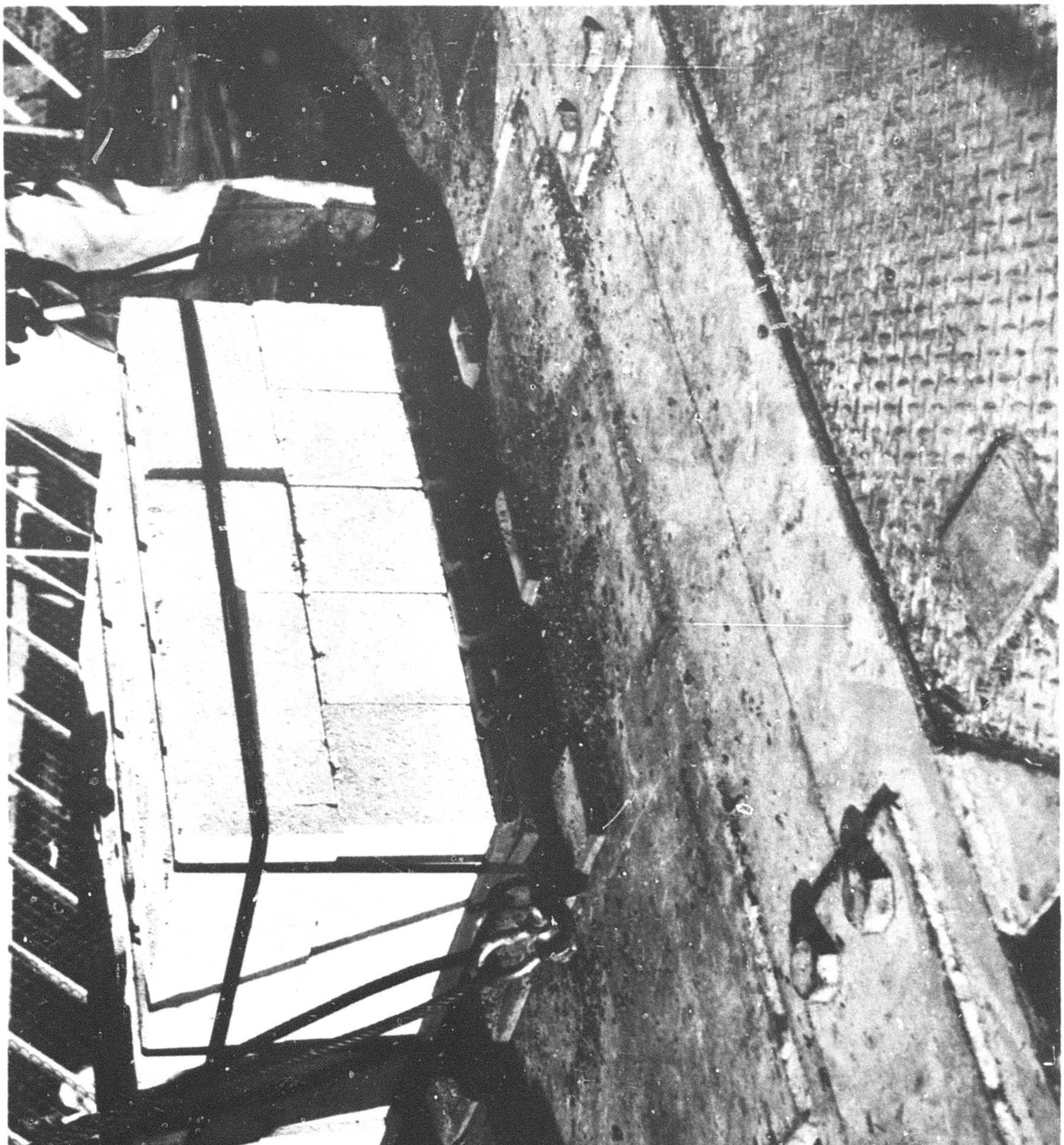


Figure 7. Pallet bars used for crane off-loading.

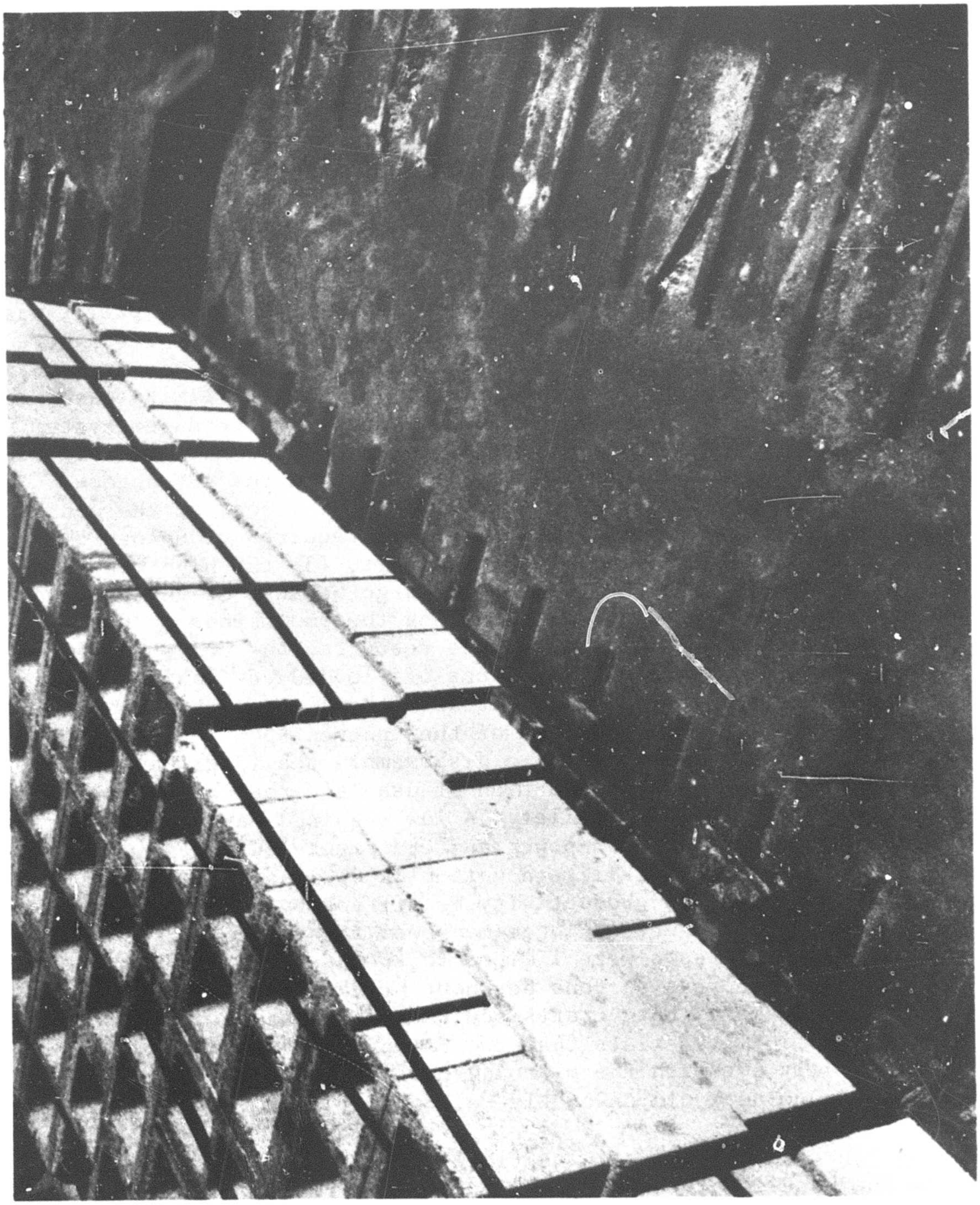


Figure 8. Traction bars can damage standard pallets.

The paucity of published experimental measurements of forklift operations is surprising. In the hopes of providing some additional information by which the off-loading times of Tables 1, 2, and 3 could be extended, five additional tests were performed. These tests examined specific portions of the forklift cycle such as engaging and lifting, setting down and disengaging, transport speed on compacted soil and sand, and truck loading operations. The observed average time and standard deviation of each of these tests are given in Appendix E.

The selection of the "optimal" cargo transfer system can not be made without definitive standards being first set for (a) the required cargo transfer rate and (b) the allowable burden for the system in terms of equipment, men and dollars. Once this has been done, the benefits of each transfer system can be weighed against the burden. The efficiency, simplicity, and all around flexibility of the RTFL and large pallet was apparent during the test program. However, as neither (a) or (b) were specified at the time of this investigation, care should be exercised in using the rankings presented in Tables 2 or 3. Special limits based upon the cost, equipment, or manpower burdens of the cargo transfer system maybe sufficient to change the relative rankings. For example, the advantage of the high off-loading rate (tons/hr) of the ACV-crane-container system must be judged in terms of (1) the cost of the containers and cranes of suitable capacity, (2) the time required to unload the cargo from the containers for inland transport, (3) the high man-power requirements, and (4) the loss of usable cargo because of the tare weight of the container. Alternatively, if during the amphibious operation man-power and equipment will be a scarce resource, the criterion for optimality might be to maximize the tons off-loaded per man hour. The selection of the forklift-large pallet as optimal under these conditions should be tempered by an evaluation of the inherent penalities of (1) the cost of pallets, (2) the time to disassemble the large pallet for inland shipping, and (3) the reduction of usable cargo capacity due to the tare weight of the large pallet. A low required cargo flow rate coupled with a scarcity of man-power and equipment could possible make the standard pallet and forklift (double pick up) the optimal cargo transfer system. The low productivity is off-set by no requirements for load consolidation hardware or large manpower requirements.

The off-loading tests were limited to the use of one MHE. The obvious method of increasing tons per hour productivity would be to add more MHE. For example, both crafts could be unloaded by two forklifts per ramp; a possibility exists that two cranes could be used with the ACV but certainly not with the planning craft since the combination of wave action and wind would undoubtly make one side of the craft difficult to work.

Load consolidation techniques (large pallet, container) while decreasing the handling time for transfer tend to reduce the cargo capacity of the craft. The usually weight limited ACV will have 15% of its 150,000 pound payload capacity lost because of the tare weight of the containers or an 8 percent loss because of large pallet tare weight. The normally

deck space limited LCM-8 was only able to place four large pallets (16.0-tons of usable cargo) whereas 27 standard pallets (27-tons) could be loaded. This amounts to a decrease of 30 percent in the transferred cargo per trip by using the large pallets instead of the standard pallets. Obviously the benefits of the decreased unloading time possible with load consolidation techniques must be weighed against the penalties of reduced craft cargo capacities.

CONCLUSIONS

1. The advantage of the increased producitivity of the NCEL large pallet and the 8x8x20 container should be weighed against the additional burdens they place upon the cargo transfer system in terms of cost, men and equipment.

2. All RTFLs of capacity of 4,000 pounds or greater should be equipped with 72" forks with a side shifting capability. This will increase the MHE productivity with standard pallets by approximately 1.8.

3. Cargo ramps should be full width and of minimal angle to provide RTFL operators with a maximum amount of maneuverability and visibility.

4. The grounding depth of the planing craft should be as shallow as possible in order to minimize the required crane fording depth and travel distance.

5. In a surf zone, the RTFL will offer a higher productivity than a crane.

REFERENCES

1. Naval Civil Engineering Laboratory. Technical Note N-1039: Beach Materials Handling, by R. W. Julian, Port Hueneme, California, September 1969 (AD 860411L)

2. Naval Civil Engineering Laboratory. Technical Report R-715: Amphibious Assault Landing Craft Program - Large Pallet Development, by J. A. Drelicharz and R. W. Julian, Port Hueneme, California, March 1971

3. NSRDC ltr OH80:MWB AALC-016 3900/3120 of 4 June 1970

4. Memorandum from NSRDC, Code A107.5, Subj: AACLP (S14-17) Advanced Craft Cargo Well Sixes for Recycle Preliminary Designs, of 12 June 1970

5. Stanford Research Institute: Marine Assault Forces and Amphibious Operation Plans (U) Systems Analysis of Amphibious Assault Craft (U) by E. H. Means and D. E. Vaughn, Menlo Park, California, August 1966 Contract Nonr-2332(OD) (CLASSIFIED)

6. The Containerization Institute, Inc., An Economic Approach to Container Material Selection, by J. B. Bonney. Seattle, Washington Spring Meeting - May 6 and 7, 1970

7. Control Systems Research, Inc.: A Critical Analysis of the State of the Art in Containeriation, by S. Berger. Arlington, Virginia, November 197C (AD 877259L) (Contract DAAK 02-70-C-0428)

8. Naval Ship Research and Development Center: Amphibious Assault Landing Craft Handling Systems Concepts, by C. C. Stevens. Annapolis, Maryland, August 1968.

9. Hunter's Point Naval Shipyard: Technical Report 2-70, Load Consolidation Test Report by R. Peterson. San Francisco, California, February 2, 1970.

10. Armed Services Technical Information Agency: The Discharge of Palletized Unit Loads Over-the-Beach to Tractor Trailers by Dunlap and Associates, Inc., Stanford, Connecticut, July 1956 (Contract No. DA 44-177-TC-344).

11. Stanford Research Institute: Systems Analysis of Amphibious Assault Craft: Vehicle Loading Test Results by M. J. Neilson., Menlo Park, California, April 1969.

Appendix A

Table A-1. Pallet Composition

I. ACV TESTS

Six (6) large pallets were assembled from 24 standard pallet.

A. Composition of standard pallets.*

	Percent of Total	Number	Type	Weight	Vertical CG (from bottom of standard pallet)
	8.3%	2	POL	@ 2573# block 96# pallet = 2669	24.7"
	16.7%	4	Ammo	@ 3800# shells 100# pallet + craddle = 3900	17.1"
75%	58.3%	14	General Cargo	@ 1305# brick 96# pallet = 1401	17.0"
	16.8%	4	General Cargo**	@ 580# brick 96# pallet = 676	12.6"

B. Composition of large pallets

The estimated weight of the large pallet is 700 lb with straps.

Percent of Total	Number		Weight	Vertical CG (from tines) 96" side	108" side
16.7%	1	½ POL, ½ Gen Cargo	8,840#	20.8"	24.5"
33.3%	2	½ Ammo, ½ Gen Cargo**	9,852#	16.0"	20.3"
50.0%	3	General Cargo	6,304#	15.9"	19.3"

II. PLANING CRAFT TESTS

Four (4) large pallets were assembed from 16 standard pallets.

A. Composition of standard pallets

Type	Weight
General Cargo	@ 1305# brick 96# pallet = 1401
General Cargo	@ 870# brick 96# pallet = 966

B. Composition of large pallet

Type	Weight
General Cargo	6,304
General Cargo	5,434
General Cargo	4,564

---

* SRI uses the following pallets mixes

5%	POL	@ 2100 lbs
20%	Ammo	@ 3600 lbs
75%	Gen Cargo	@ 1500 lbs

** The lighter general cargo pallets were required so the large pallets containing 2 standard ammo pallets and 2 general cargo pallets would be below the 10,000 pound design limit of the large pallet.

Appendix B

EQUIPMENT LIST

ACV Tests

(1) Terex 72-31 MP 5T rough terrain forklift (48-inch load center).
(1) 25T rubber tired self-propelled crane (60' boom).
(1) 8x8x20 steel container.

Planing Craft Tests

(1) Terex 72-31 MP 5T rough terrain forklift.
(1) 5T crawler crane (50' boom)
(1) 25T crawler crane (60' boom)
(1) LCM-8
(1) LCU (1625 series)

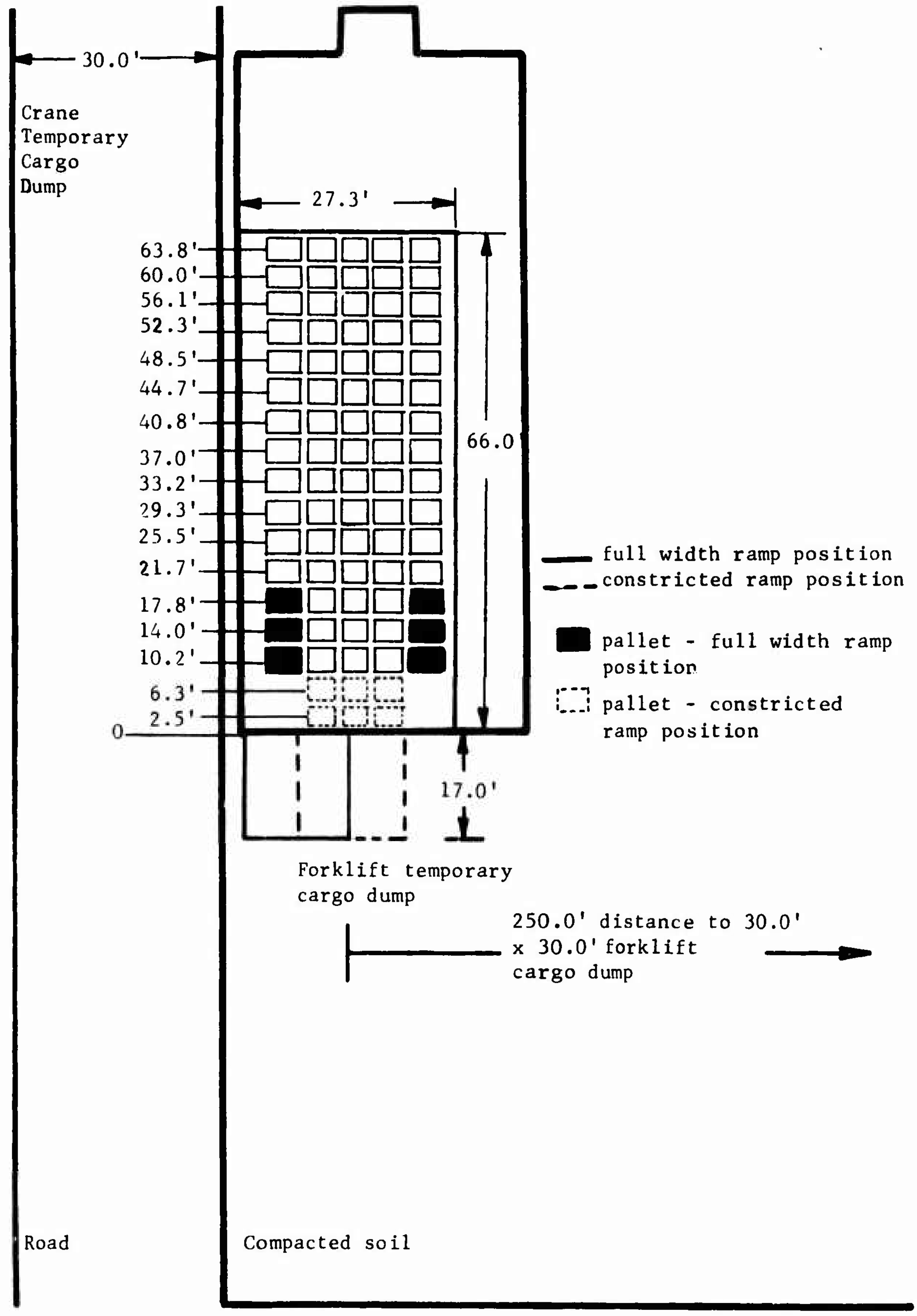


Figure C-1. Loading diagram - ACV (standard pallet)

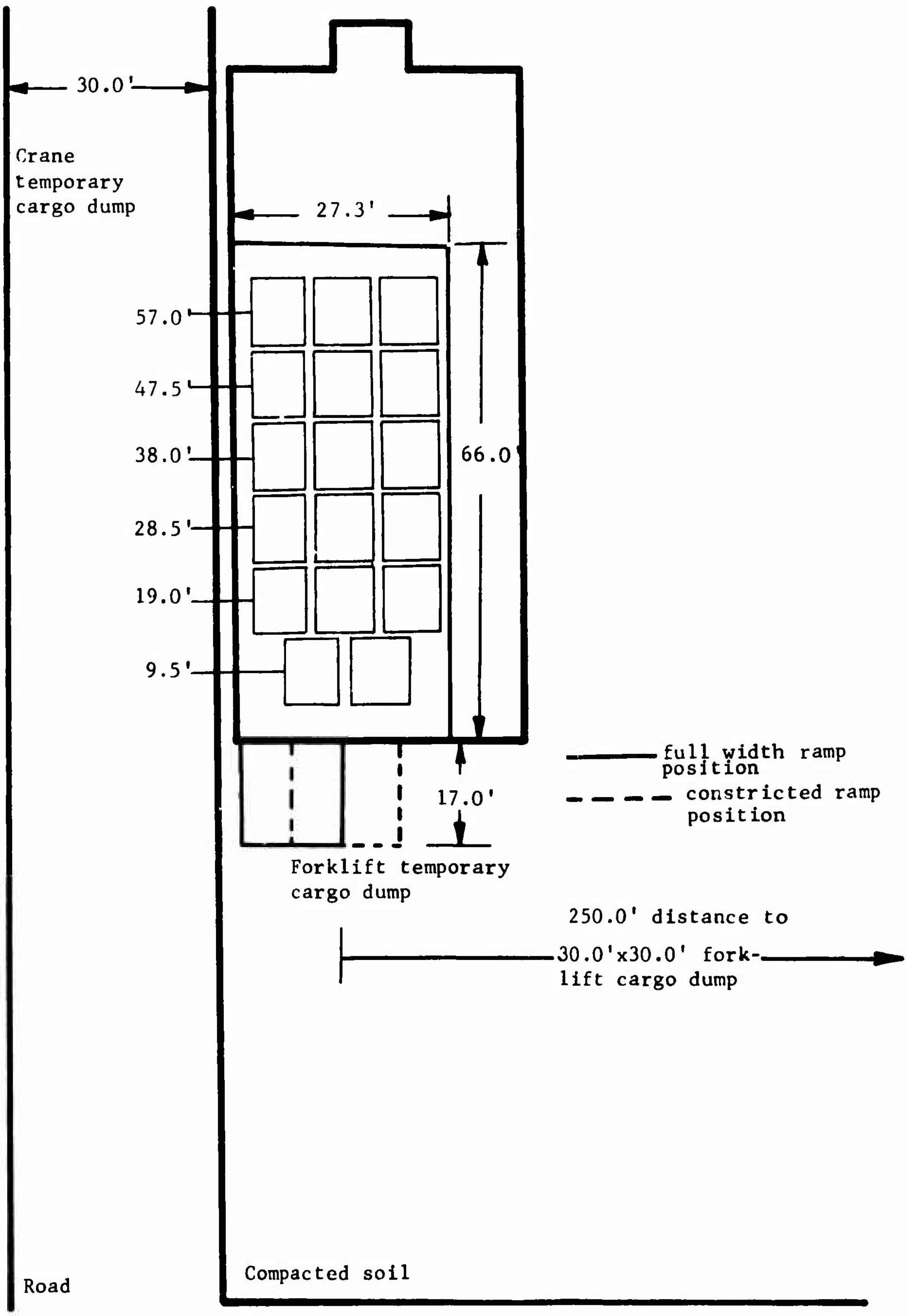


Figure C-2. Loading diagram - ACV (large pallet)

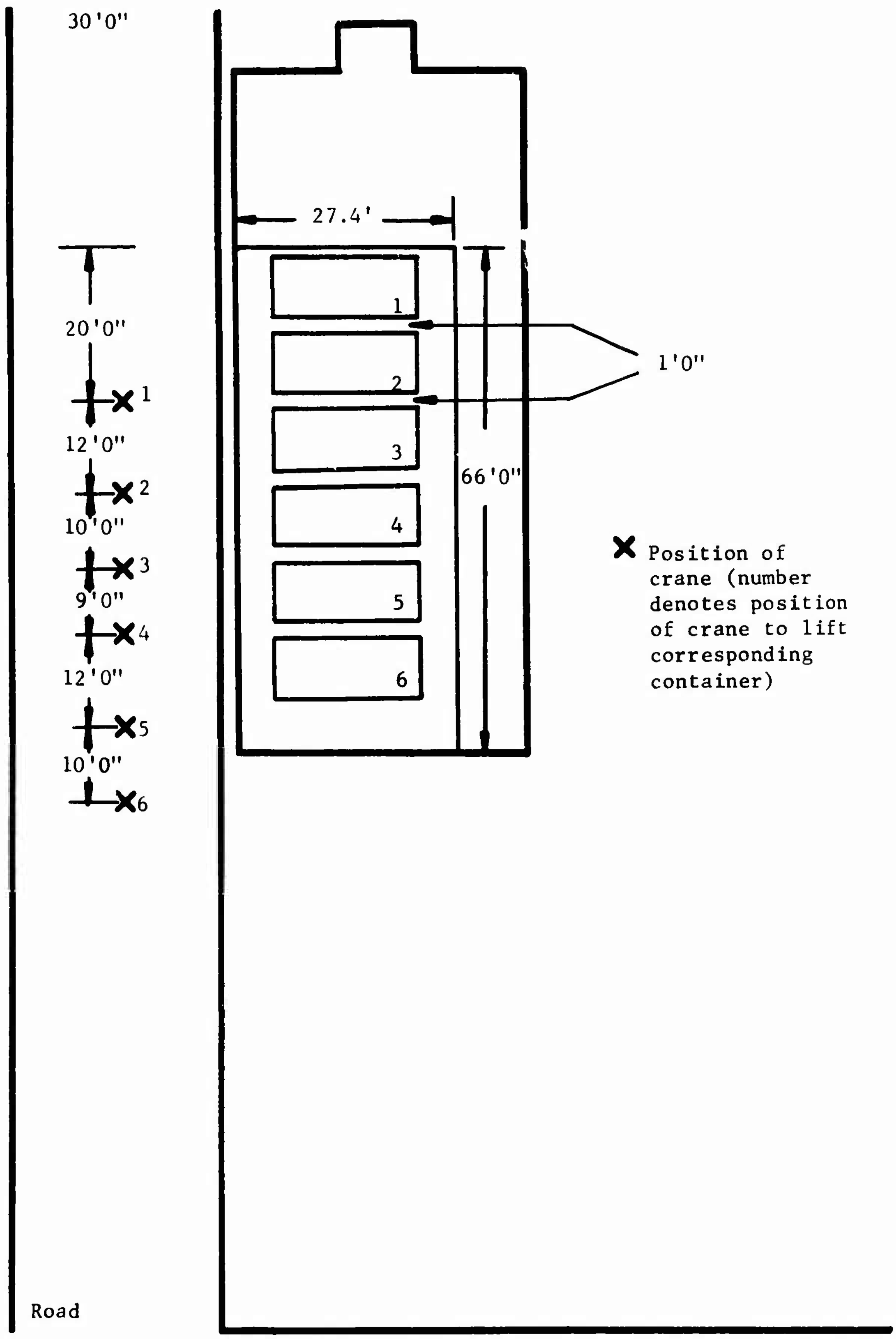
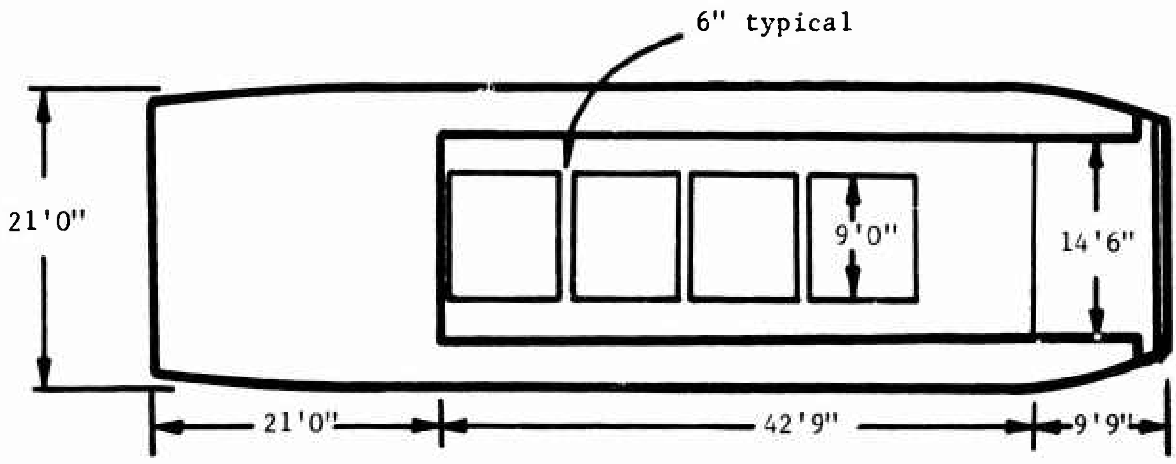
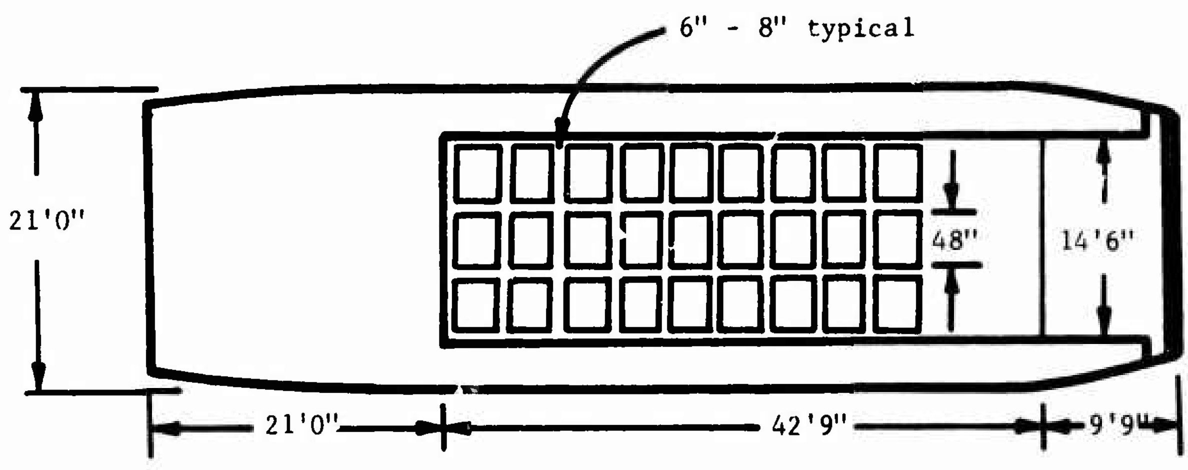


Figure C-3. Loading Diagram-ACV (Container)

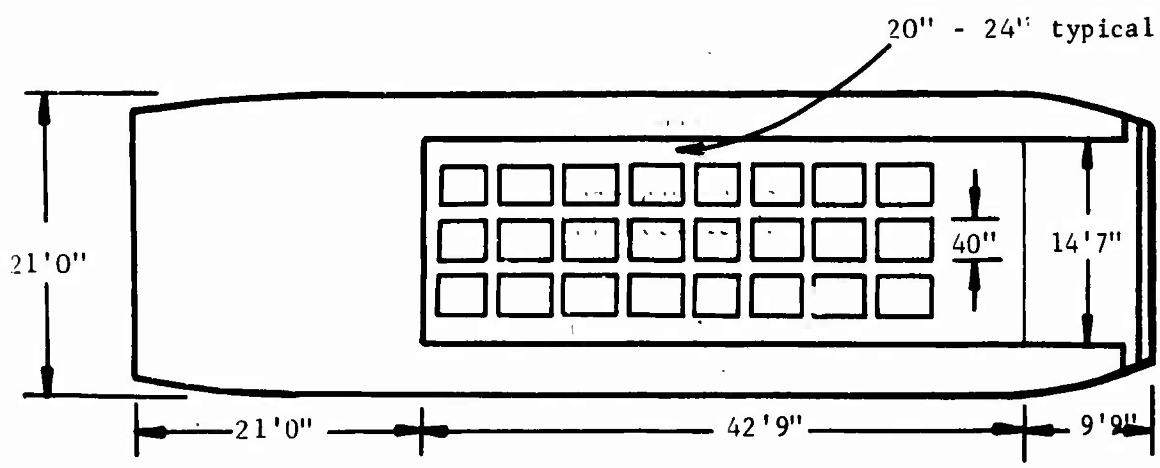


Large pallets



Standard pallets
(Crane off-loading)

Figure C-4. Loading diagram - LCM-8.



Standard pallets
(RFTL off-loading)

Figure C-5. Loading diagram - LCM-8

Appendix D

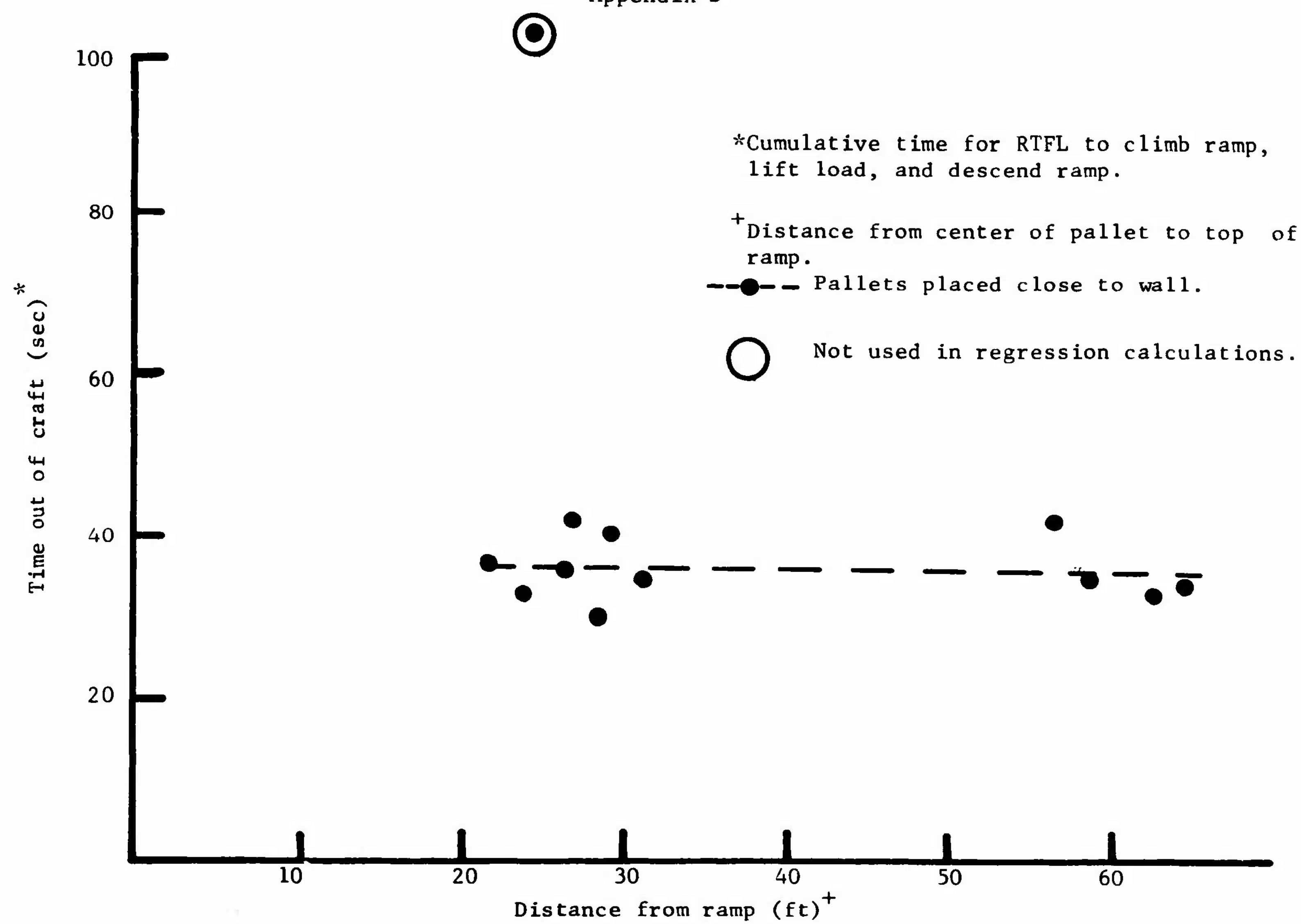


Figure D-1. Off-loading times for ACV loaded with standard pallets (constricted ramp).

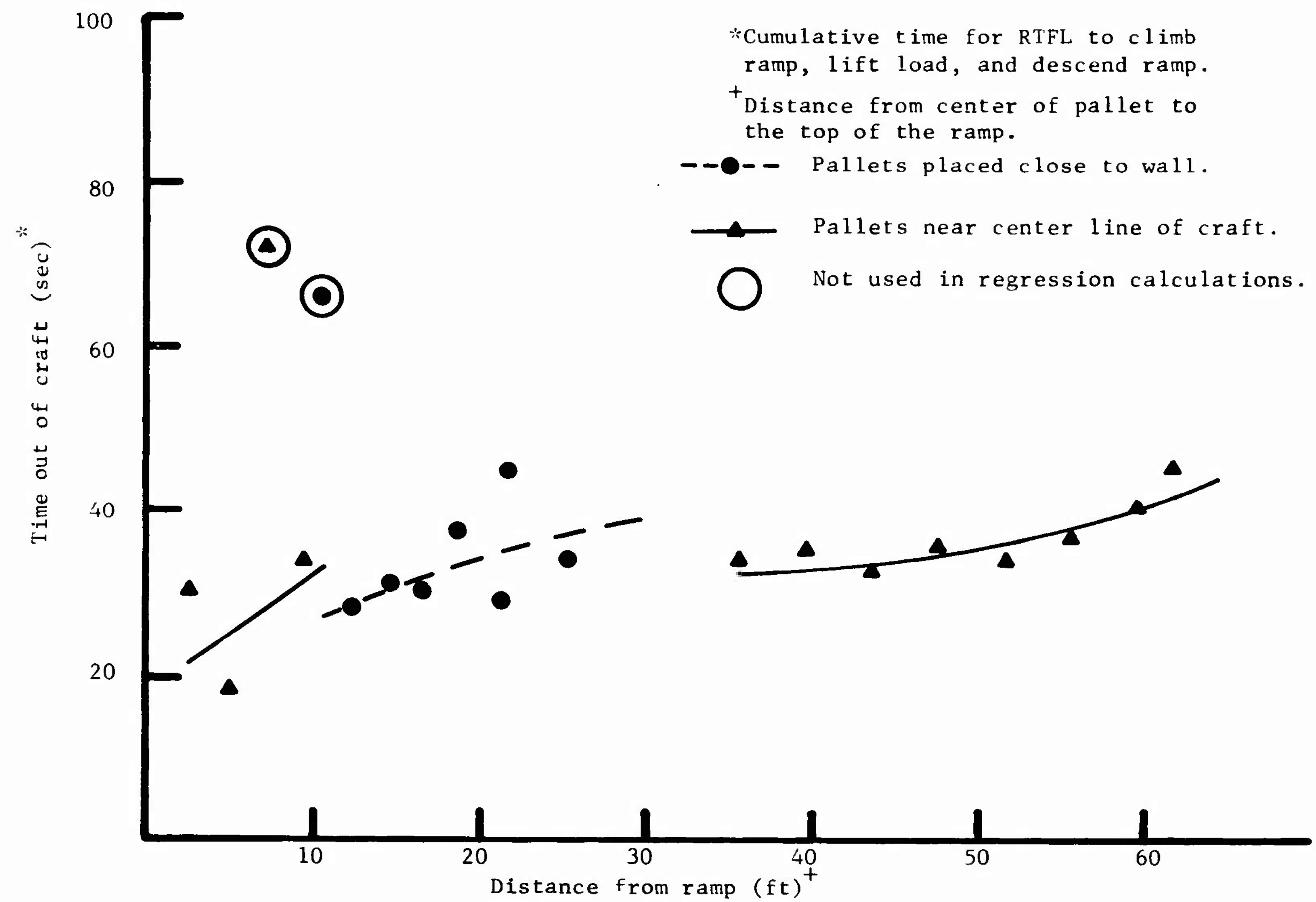


Figure D-2. Off-loading times for ACV loaded with standard pallets (full-width ramp).

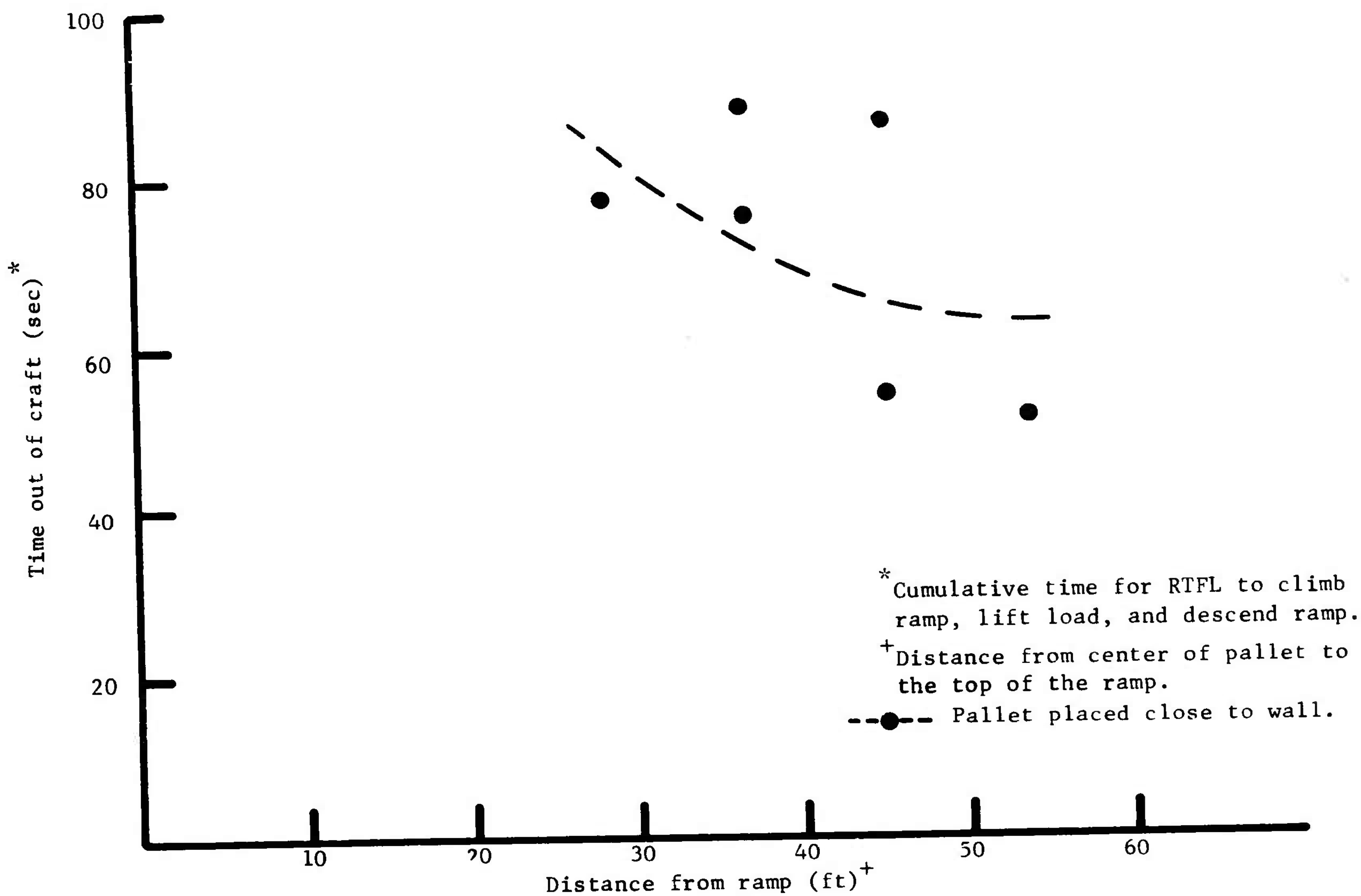


Figure D-3. Off-loading times for ACV loaded with NCEL large pallets (constricted ramp).

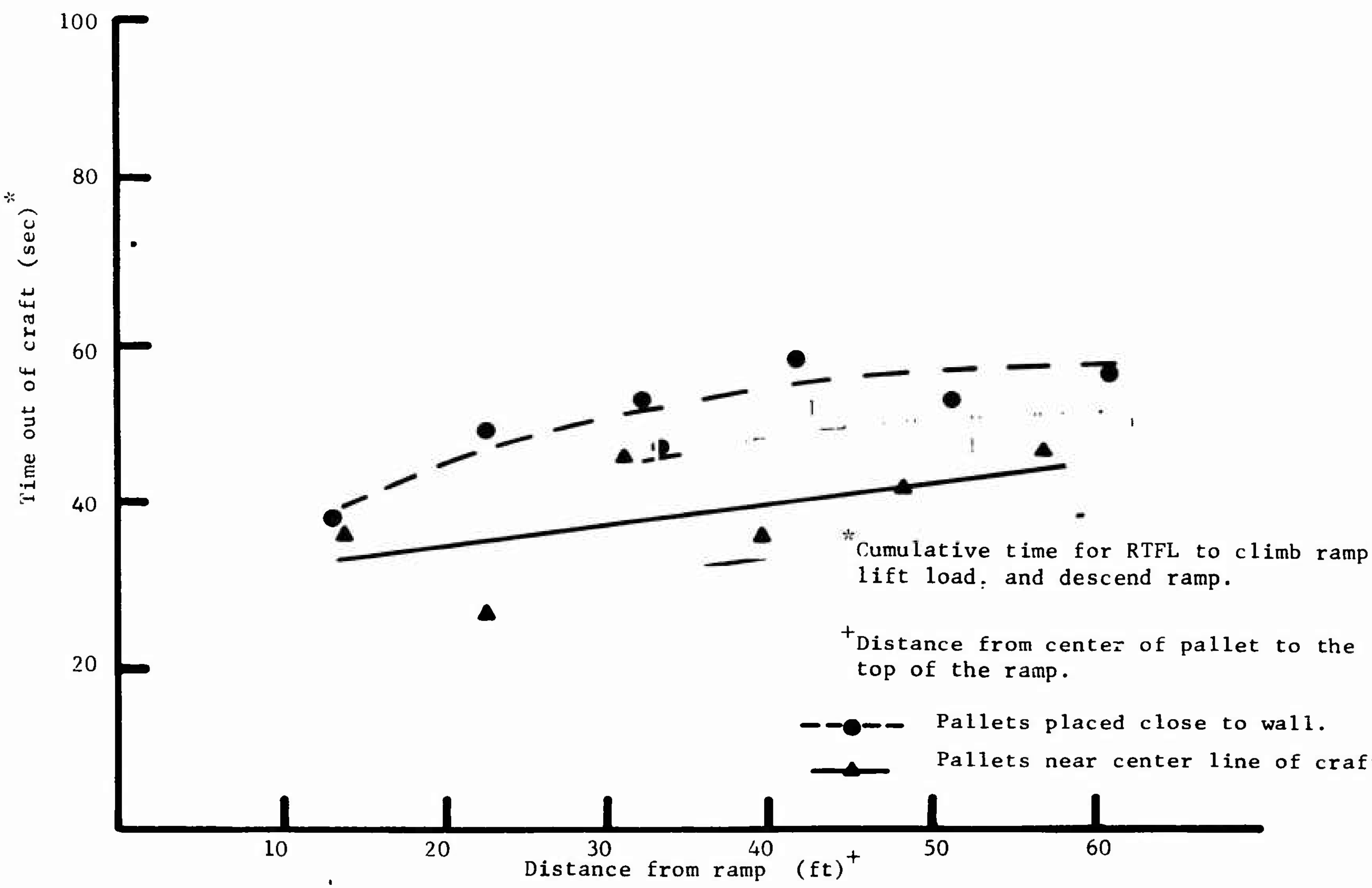


Figure D-4. Off-loading times for ACV loaded with NCEL large pallets (full width ramp).

Appendix E

Table E-1. Analysis of Forklift Operations (ACV)

Cargo	Move Pallet 250' to Cargo Dump (sec/pallet)	Time to return to ACV (no load) (sec)
6 large pallets	43.0 σ = 3.03	29.4 σ = 1.95
5 large pallets	34.7 σ = 2.07	28.8 σ = 3.06
8 standard pallets	30.6 σ = 0.92	26.0 σ = 1.31
8 standard pallets	32.0 σ = 2.78	26.1 σ = 1.64

σ = standard deviation

Tests performed on compacted soil.

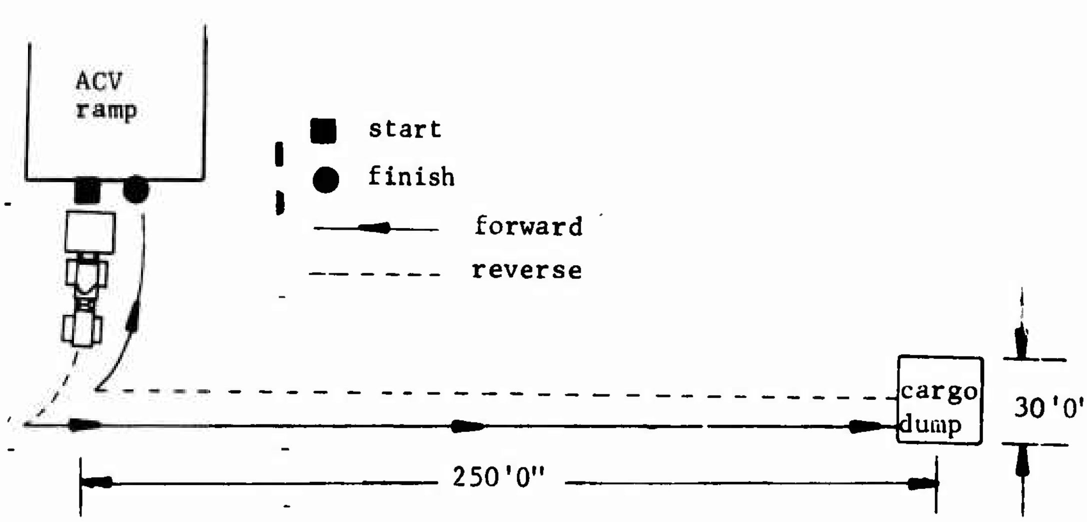


Table E-2. Analysis of Forklift Operations (Pallets)

Cargo	Pick-up Cycle (sec)				Set-down Cycle (sec)		
	Move 20'*	Start to Engage	Lift Off	Move 25'	Move 20'*	Set Down	Disengage
5 large pallets	3.0 σ=1.22	2.8 σ=0.84	3.3 σ=0.96	3.0 σ=0.71	2.4 σ=0.55	3.2 σ=1.30	2.4 σ=0.55
5 standard pallets	2.4 σ=0.55	2.0 σ=0.0	2.0 σ=0.0	3.6 σ=0.55	2.2 σ=0.45	2.2 σ=0.45	2.2 σ=0.45
5 - two standard pallets	2.4 σ=0.55	2.0 σ=0.0	2.6 σ=0.55	4.2 σ=0.45	3.8 σ=3.95	5.3 σ=2.87	3.0 σ=1.15

σ = standard deviation

*At this point the forklift reduces speed and then travels an additional 5' to either engage or set down the pallet.

Tests performed on compacted soil.

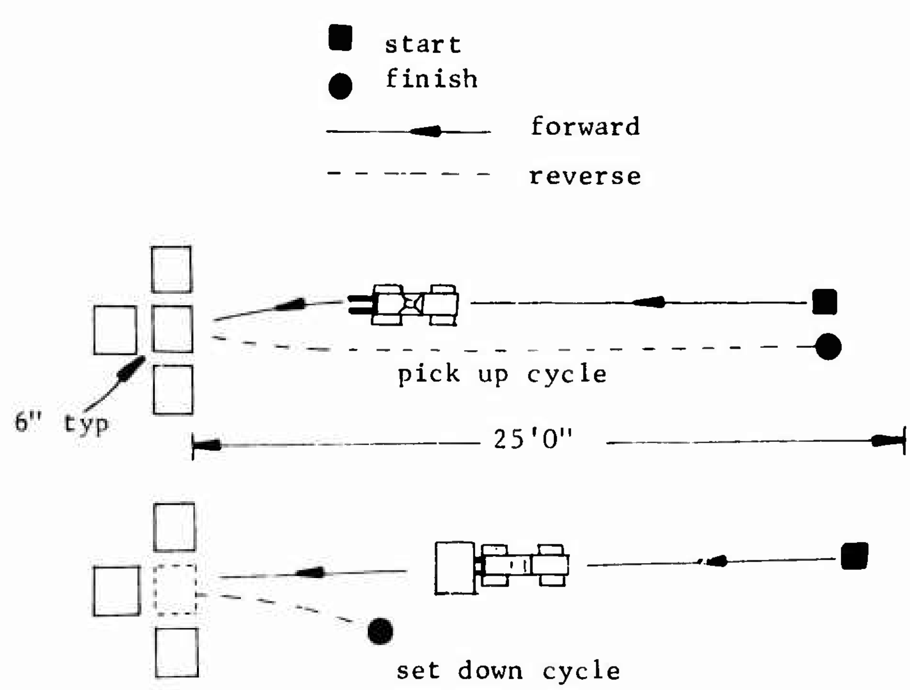


Table E-3. Analysis of Forklift Operations (Container)

Cargo	Pick-up Cycle (sec)				Set Down Cycle (sec)		
	Move 95'*	Move Last 5 ft	Lift Off	Move 100'	Move 95'*	Set Down	Disengage
5 8x8x20 containers (empty)	8.0 σ=1.0	1.8 σ=0.45	2.4 σ=0.55	9.4 σ=1.34	8.0 σ=0.0	2.8 σ=0.45	2.2 σ=0.45

σ = standard deviation

*At this point the forklift reduces speed and then travels an additional 5' to either engage or set down the container.

Tests performed on asphalt

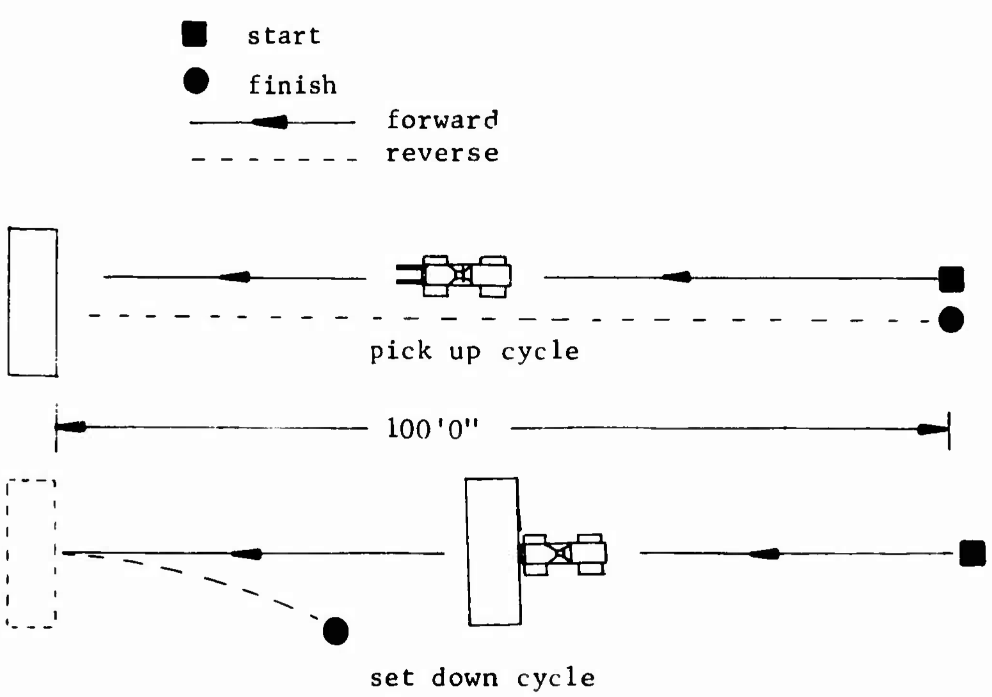


Table E-4. Analysis of Forklift Operations

Cargo	Pick-up Cycle (sec)				Set Down Cycle (sec)		
	Move 145'*	Move Last 5 ft	Lift Off	Move 150'	Move 145'*	Set Down	Disengage
5 Large Pallets	14.2 σ=0.84	3.3 σ=0.90	5.5 σ=2.38	19.8 σ=4.92	14.4 σ=1.34	4.0 σ=1.00	3.0 σ=0.0
5 Standard Pallets	14.2 σ=1.10	2.8 σ=0.44	2.6 σ=0.55	17.0 σ=1.22	15.6 σ=1.52	4.2 σ=1.12	2.8 σ=0.84
5 8x8x20 Containers (empty)	11.2 σ=0.84	4.6 σ=2.51	3.2 σ=0.44	16.6 σ=1.34	14.8 σ=1.48	6.2 σ=2.68	2.3 σ=0.44

σ = standard deviation

*At this point the forklift reduces speed and then travels an additional 5' to either engage or set down the cargo.

Tests performed on asphalt

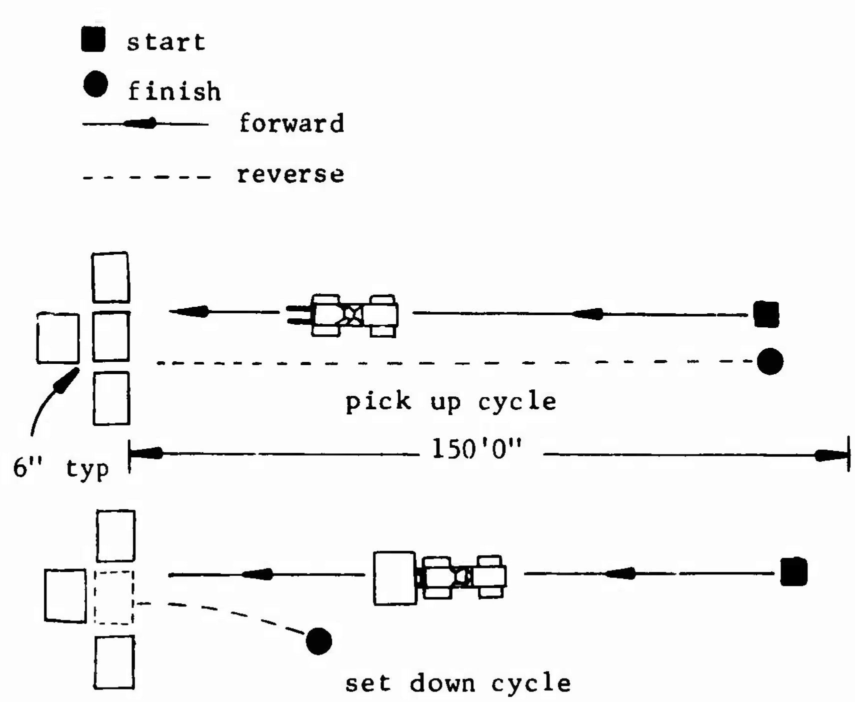


Table E-5. Analysis of Forklift Operations
(loading 2½T truck)

Cargo	Pick-up Cycle (sec)			Set Down Cycle (sec)		
	Move 20'*	Move Last 5 ft	Lift Off	Move to 5' of Truck*	Set Down	Disengage
Large Pallet	4.0 σ=0.0	3.3 σ=0.50	3.5 σ=0.58	10.0 σ=1.41	4.3 σ=0.50	3.0 σ=0.0
Standard Pallet	12.3 σ=4.04	4.3 σ=0.58	6.5 σ=3.11	13.8 σ=3.10	12.3 σ=7.97	10.5 σ=13.67
Standard Pallet	6.5 ---	3.0 ---	2.8 σ=0.96	11.5 σ=1.29	6.3 σ=1.26	4.5 σ=1.73

σ = standard deviation

*At this point the forklift reduces speed and then travels an additional 5' to either engage or set down the pallet.

Tests performed on sand.

Sample size

(a) large pallet, 5 runs @ 1 pallet per truck.
(b) standard pallet, 1 run @ 4 pallets per truck.